3D subduction modelling of the Betic-Rif Alboran region.

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Introduction

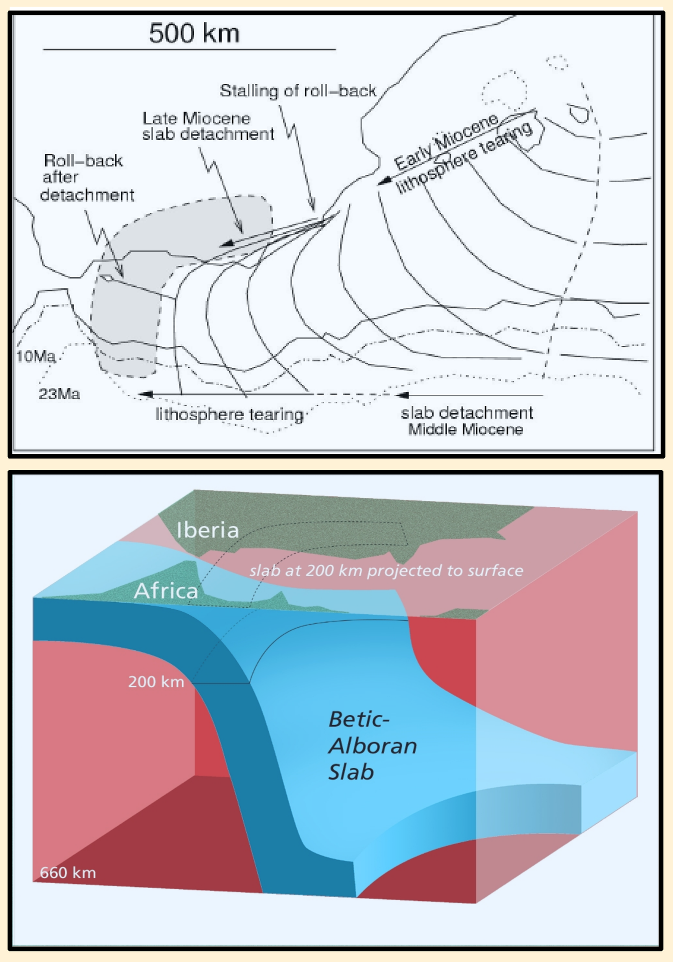


Figure 1. Kinematic evolution of slab roll-back in the Betic-Rif-Alboran region and the interpretation of the 3-D geometry of imaged structure below it.

Our project* is concerned with the 4D evolution of Western-Mediterranean region from ~30 Ma until the Present. Slab rollback and lithosphere tearing play an important role in the evolution of this region and affects the development of surface geology (Spakman and Wortel, 2004).

The results of our 2D numerical simulations(Chertova et al., 2012) demonstrates that open boundary conditions have important advantages in comparison with free slip, namely: no boundary influence on the subduction dynamics process and possibility to decrease the domain size which allows us significantly reduce computational expenses.

Now our research is focused on 3D models. We start from the reconstruction of the subduction process in the Betic-Rif Alboran region. This region has a long and complicated subduction history, which consists of slab rollback, lithosphere detachment and tearing processes leading to a narrow curved subduction zone (Spakman and Wortel, 2004). So far analogue models failed to reconstruct such a high-curved structure. We have implemented and tested the open boundary conditions in a 3D setting, which allowed us to significantly decrease the domain size. Different initial plate tectonic settings and kinematic boundary conditions are now being tested in order to reconstruct this complex subduction process.

Model description

We perform our experiments both with a 2D and 3D Eulerian mesh, with open and closed boundary conditions on the side boundaries. Open boundaries are implemented by imposing a lithostatic pressure condition for the normal stress on the boundary, $P_{lith}=\sigma_n$, which proves to minimize the side boundary influence on the flow pattern around the slab. We solve for the coupled equations of conservation of momentum and energy in Boussinesq approximation for an incompressible flow using SEPRAN, a general FE modeling package.

$$\nabla \cdot u = 0$$
$$-\nabla P + \nabla \cdot \tau = f(\rho)$$
$$\rho c_p \frac{dT}{dt} - \nabla \cdot (\kappa \nabla T) = 0$$

Rheological structure

We use a composite rheology consisting of pure diffusion, dislocation creep and stress-limiter mechanism(only for the 3D experiments). The top of the subducting lithosphere and low viscosity wedge (LVW) consists of a low-viscosity material (10^{19} Pas) which represents hydrated sediments and basalts. The material is defined on tracer particles, that are advected by the flow.

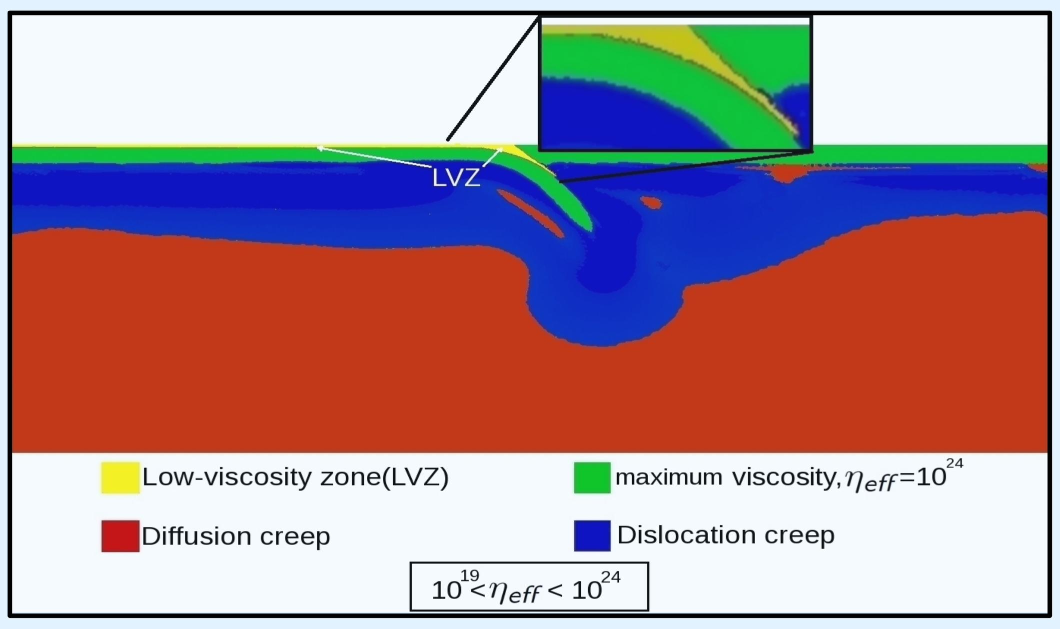


Figure 2. Dominant deformation mechanism for the 2D subduction model with open side boundaries.

Results of 2D modelling (Chertova et al. submitted 2012)

Effect of different boundary conditions on the subduction dynamics.

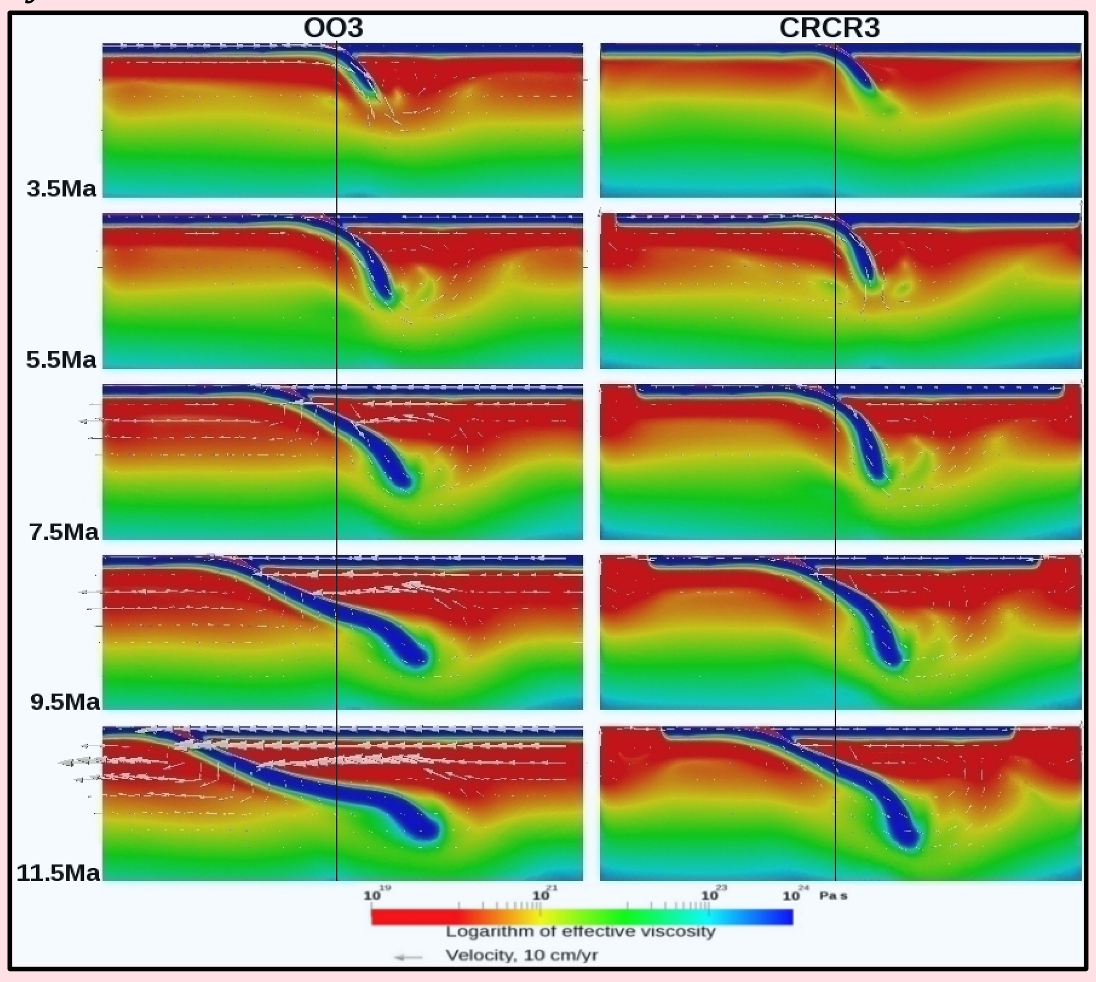


Figure 3. Evolution of the subduction process for model OO3 with open boundaries and model CRCR3 with closed boundaries. Arrows show the direction and magnitude of flow field.

effect of the model aspect ratio. Velocity scaling.

For the models with *open boundaries* we have found an iterative method that allows us to scale the velocity between models with different aspect ratios. This iterative scaling procedure is based on equivalence of the total dissipative power for the models and has to be applied during the computational process.

For the models with *closed boundaries* we cannot apply velocity scaling due to lateral variations of the flow close to the side boundaries.

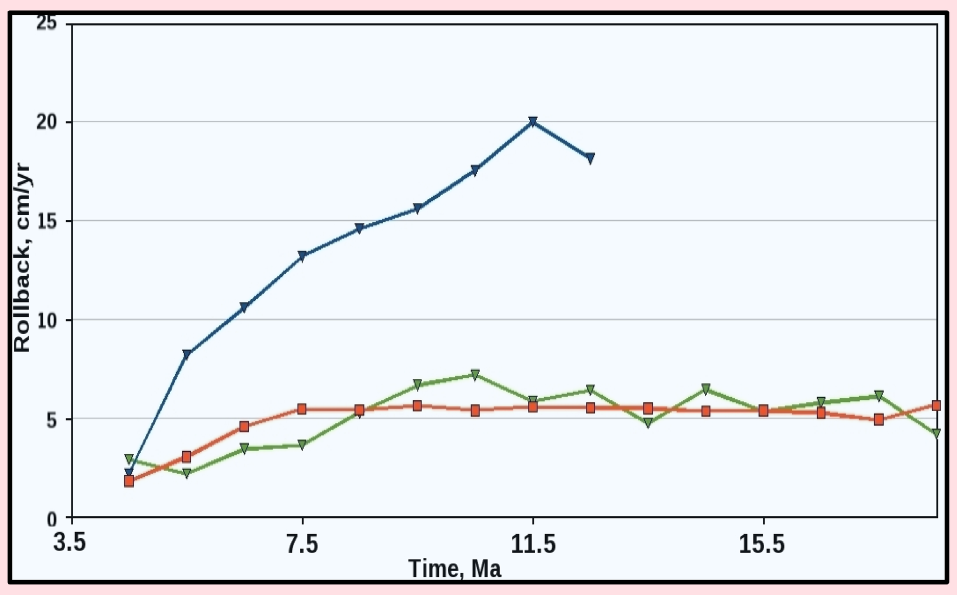
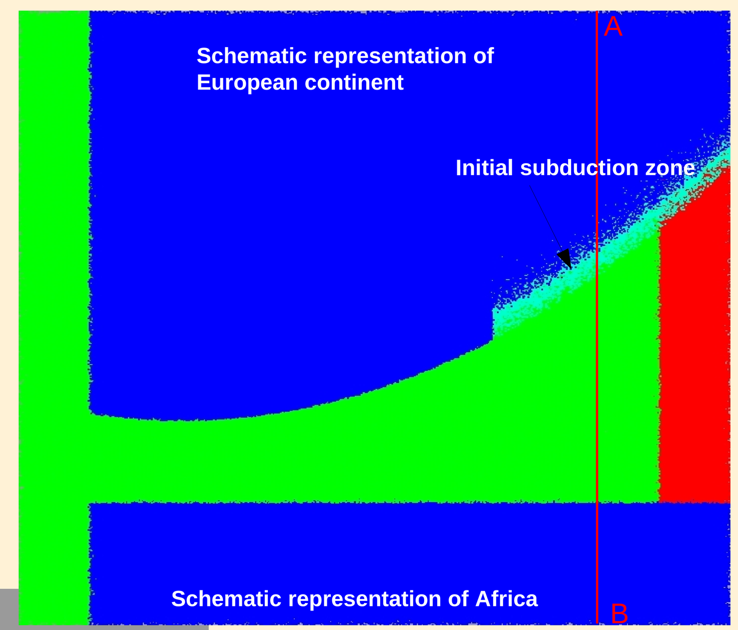


Figure 4. Evolution of the speed of rollback for two models: model OO3 with aspect ratio 3:1 (blue line), and model OO6 with aspect ratio 6:1 (red line) and scaled speed of rollback for the model OO3 with aspect ratio 3:1 (green line)

3D Numerical modelling of the subduction process in the Betic-Rif Alboran region. Model setup.

Figure 5. Idealized geometry of the Betic-Rif-Alboran region, 30Ma.
Blue - continental lithosphere
Green - oceanic lithosphere
Light blue - initial subduction zone
Red - young oceanic crust
Note: the weak crustal layer on the top of the subducted oceanic lithospere and weak continental margins are not presented.



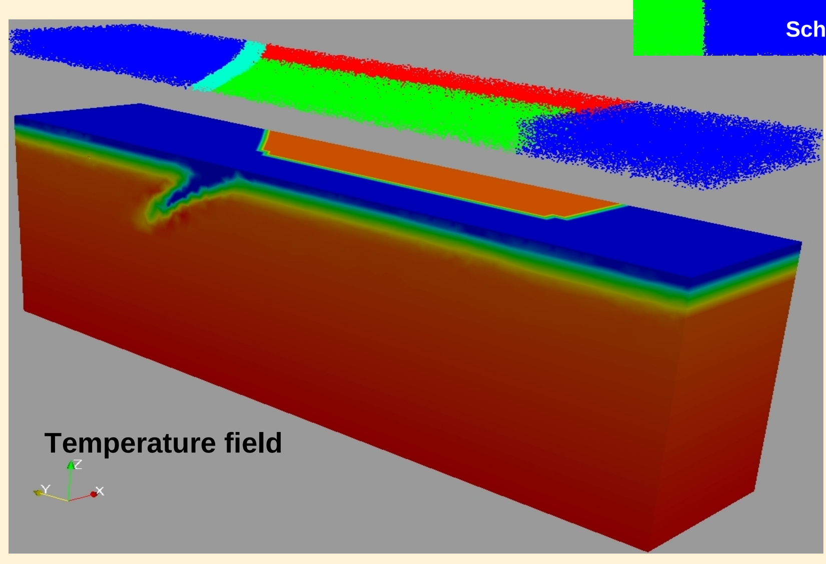


Figure 6. Initial temperature field for the Betic-Rif-Alboran region along the crossection AB in the Figure 5.

3D Numerical modelling of the subduction process in the Betic-Rif-Alboran region. Preliminary results.

We investigate the influence of diffirent initial settings and boundary conditions on the development of the subduction process in the Betic-Rif-Alboran region such as: width and different weakening mechanisms(e.g. artificial decreasing the viscosity or lower yield stress values) for the weak continental margins, different side boundary conditions (open vs free slip), different intraplate stresses for the continental lithosphere. Under these conditions we observe the development of different subduction processes in our models. Our purpose is to integrate tectonic reconstructions with the driving processes and to test various propositions for tectonic evolution. Model results will be compared to present-day mantle structure imaged with tomography (Spakman and Wortel, 2004).

Figure 7. Evolution of the subduction process in the Betic-Rif-Alboran region, 15Ma. The roll-back process develops during the simulation.
Red color - continental lithospere, yellow – oceanic, green – weak continental margins, blue – weak crustal layer on the top oh the oceanic lithospere. Purple color show the temperature contour of the bottom of the lithosphere.

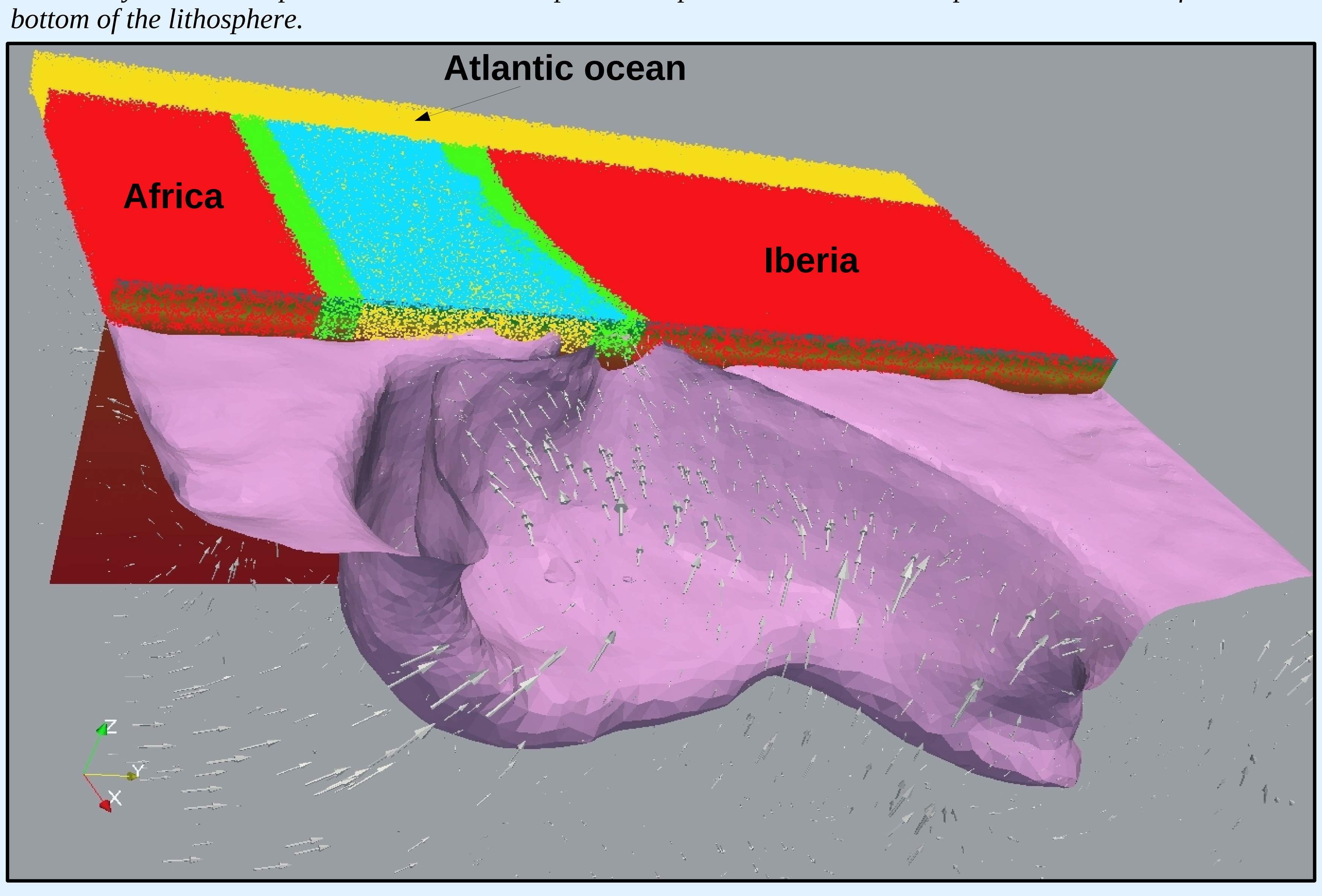
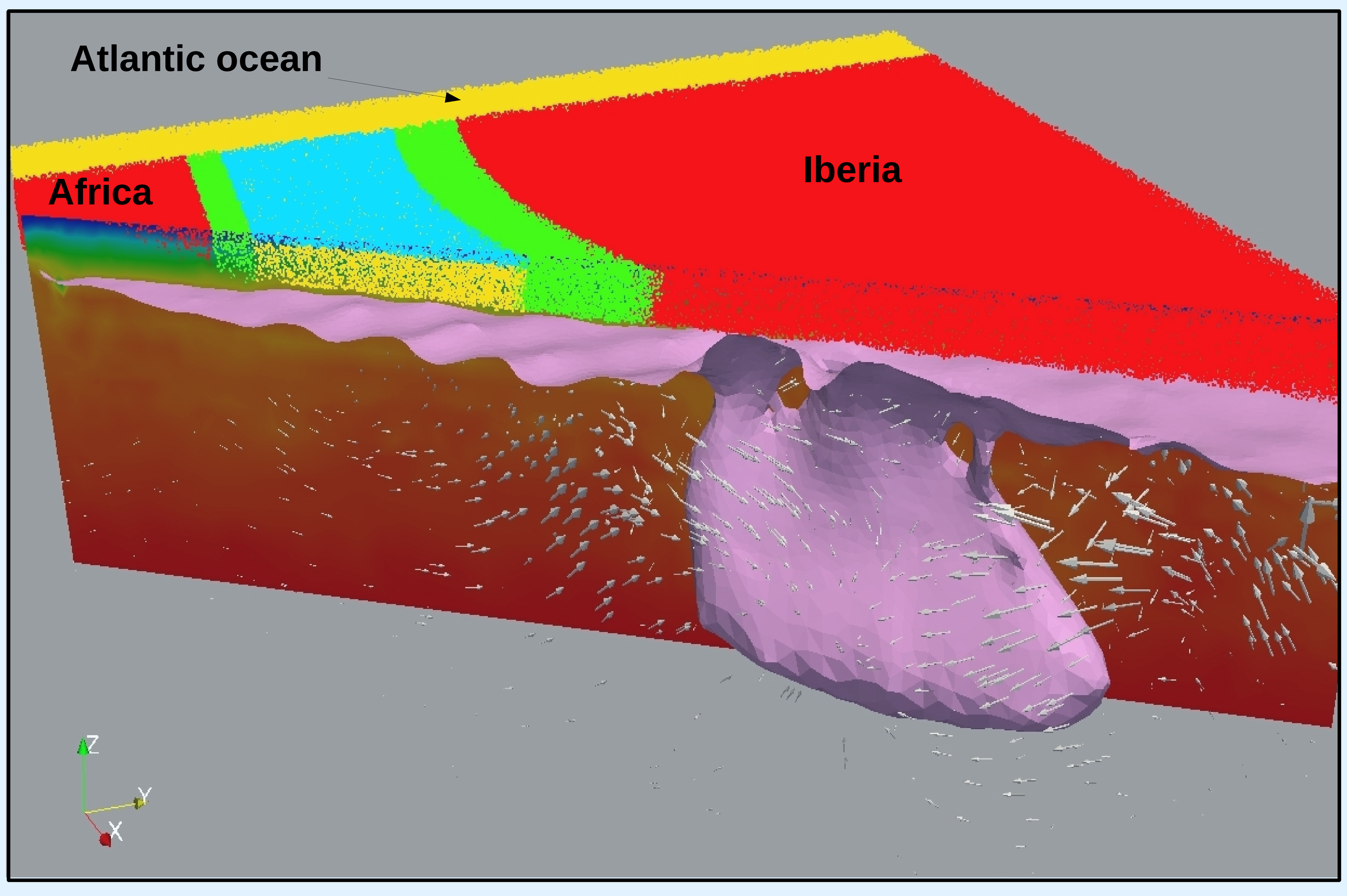


Figure 8. Evolution of the subduction process in the Betic-Rif-Alboran region, 20Ma. The slab break-off develops due to the lower value for the yield stress.
The legend is the same as in Figure 7.
Arrows show the direction and magnitude of flow field.



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